C-1

POKREFKE

RESPONSE TO DAVINROY'S COMMENTS

Response to Rob Davinroy's comments on WES Movable-Bed Modeling

1. **Discharge Scale**. As Rob stated, we operated based on empirical conditions, which was a result of an inability to follow Froude criteria in our studies. I have a concern when I am told that we "...cannot say it (model operation) was directly scaleable to the prototype or was simulating a scaled prototype hydrograph." We "blocked" prototype stage and discharge hydrographs, scaled the discharge based on a variable discharge relation over the range of flows covered in that blocked discharge hydrograph, introduced those flows at the upstream end of the model, and maintained the appropriate water level elevation, based on the blocked stage hydrograph for a particular discharge, at a selected location in the model. **I**, see that as scaling hydrographs, both stage and discharge, and indicative of the fact that we were "...representing the stage and flow of the prototype."

I have pondered and pondered this, and for the life of me cannot understand how Rob could make the above statement. The key to WES movable-models is that we were aiming at obtaining a reasonable (empirical basis) amount of movement of the model bed material. We did not want movement to be too little nor too much. In my opinion our operation was based on us reproducing the physics of the discharge and stage using classical hydraulics. Considering the continuity equation that we all learned in Basic Hydraulics, Q=AV, we controlled the discharge (Q) based on the volume of water introduced in the model, we constructed a scaled model which controlled the width (part of A), and we maintained a desired stage (the other part of A). This allowed us to have partial control of the velocity (V) to ensure the desired bed material movement. The remained of the control of velocity was obtained with the total slope (natural, distortion, and supplemental slopes). No matter what open channel flow equation one prefers, Chezy or Manning, the hydraulic radius (R) and slope (S) are the main variables. The hydraulic radius is controlled by the model construction scales and maintained stage, and the slope is a function of the model scales and supplemental slope added. To **me**, it appears that we left nothing to chance and maintained control on as many of the variables dealing with the movement of water and sediment as possible. No doubt there was judgment involved, back to the words *reasonable model bed movement* again, but we continually monitored model inflow, maintained, monitored and recorded water surface elevations over the entire length of the model, and observed and recorded the resulting model bed material. It was a procedure that was thought out, repeatable, and reasonable, so that was what we did model after model.

2. **Sediment type**. Rob had no additional comments.

3. **Adjustments of Rails**. I do not know what Rob means by saying that "...adjustments were made to the bed above and below the pivot point describe the operation of the model. This should be called out." The point I tried to make earlier was that when model scales were selected and reference elevations selected prior to construction, we established an elevation for the top of our rails and that elevation was tied to a benchmark and used **everywhere** on the rails as our datum. In reality the supplemental slope was set in those rails, but, as stated by Rob, "...the datum was adjusted accordingly." was **not done**. If we had established the top-of-the-rail elevation as +500-ft, that is the number

we used to set our sounding stick anywhere and everywhere on the model. Therefore, as far as collecting data and presenting results of the bed configuration, our datum was fixed and never *adjusted* once the top-of-rail-elevation was selected prior to construction.

Last paragraph. As far as Rob's point on flow visualization presented in WES reports goes, I stand corrected (bet you never thought you would hear me say that). Although it is sad to see that 2 of the 3 reports Rob referenced were before even **Claude or I** were born, and all 3 were published before any of us had graduated from high school. Also, please note that the visualizations were presented with specific stages identified, which helped the reader see effects of plans with differing flow conditions.

Relative to Rob's concern of my "criticism" of the Morgan City micro-model study, I said nothing that I have not said from the early contacts I had with MVS and the micro-model technology. That concern (or criticism, if that is the word you want to use) is that by not making some type of a connection in the micro-model of prototype discharge and stages, the micro-model velocities always seem to be **extremely** exaggerated. Flow visualization is conducted with no appreciation for what prototype flow condition may be represented in the micro-model. On the Morgan City study the visualization is listed on the plates as low and high, but that is low and high flow in the micro-model with no stated or known (my opinion) stage or discharge relationship to the prototype. To me, the exaggerated velocity will tend to give smooth pathlines because of the simple fact that it is harder for the faster moving velocities to change direction. When I looked as micro-model studies with emergent dikes in the plan I see little evidence of what I have called a "wing-tip vortex" off of the streamend of dikes. Also, eddies within dike fields appear to be moving at a relatively high velocity, indicating to me that the velocities in the main channel passing the dike fields are moving very rapidly.

Therefore, I did some digging to try and come up with some information on prototype, WES movable-bed modeling, and micro-modeling that would help put things in perspective for me. I went to Rob's thesis from UMR as a starting point for my search. On pages 58 and 59 of his thesis, in Sections 2.a. through 2.c., Rob addressed the issue of Froude numbers in the prototype, WES Dogtooth Bend Movable-Bed Model, and his Dogtooth Bend Micro-Model. The Froude numbers that Rob computed were 0.1057, 0.3524, and 0.6221, respectively. Rob also gave Reynolds numbers of $6.775X10^6$, $21X10^3$, and $1.1\ X10^3$, respectively. That says that in the WES Model, the Froude number was about 3.3 times the prototype and in the Micro-Model the Froude number was about 5.8 times the prototype. For Reynolds number, the WES Model Reynolds number was about 0.3% of the prototype's Reynolds number, and the Micro-Model Reynolds number was about 0.02% of the prototype's Reynolds number. Rob also stated that based on his computed Reynolds numbers, the prototype and WES Dogtooth Bend Movable-Bed Model were in the turbulent flow category, and the Dogtooth Bend Micro-Model was in the transitional or mixed state zone. Looking at these numbers, I concluded that with the Micro-Model operating at a relatively high Froude number with transitional flow, some degree of instability had to exist. At this point I got my UMR Basic Hydraulics book out, **Fluid Mechanics with Engineering Applications** by Daugherty and Franzini. Daugherty and Franzini never addressed the issue of turbulent or laminar flow in open channels. Relative to *pipe flow*, it was stated that a Reynolds number below the "true critical Reynolds number" of 2,000 is difficult to maintain and when the Reynolds number for the flow is less than 4,000, the flow is "inherently unstable." Therefore, I decided to look at the flow issue somewhat differently to help me understand what was going on in the WES Movable-Bed Model and Micro-Model.

Since we are talking open channel hydraulics, the fact remained that in the WES Movable-Bed Models and the Micro-Model, although accomplished by different methods, some type of stage and discharge hydrographs were passed through the models. I first went to Franco's 1978, Instruction Report (H-78-1) to address the discharge relation curve discussed in paragraphs 43 through 45, paragraph 46.e., and presented (for a coal bed model) in Figure 2. Based on the model scales (1:120 horizontal and 1:80 vertical) the Froude, theoretical discharge relation computes to be 1:85,865 (model to prototype). Considering Figure 2, for a low discharge (which also would correspond to a low stage based on typical stage-discharge rating curves) the discharge relation for a prototype discharge of about 17,000 cfs would be 1:30,000 and for a high prototype discharge of about 700,000 cfs the discharge relation would be 1:90,000. That means that the velocities in the WES Movable-Bed Model would be increased by a factor of about 2.9 for the low discharge and would be virtually undistorted (increased) at the high discharge. In the write-up I prepared for Andy, this is exactly what I said.

I then went to Rob's thesis and Chapter III (Procedure), Section C.3. (Discharge Relation Curve) including Figure 18. The scales of the Dogtooth Bend Micro-Model presented in the thesis were 1:15,000 horizontal and 1:1,200 vertical. That gives a computed, Froude theoretical discharge relation of 1:623,539,829. Considering Figure 18 (although I did have some question about the units of the prototype discharge), I selected a low discharge having a discharge relation of 1:135,000,000 and a high discharge with a relation of 1:150,000,000. Following the same thought process as I took on the WES Movable-Bed Model, I computed a velocity increase for the low prototype discharge of 4.6 and an increase for the high prototype discharge of 4.2.

The effect of stages in the WES Movable-Bed Model and Micro-Model could have an impact on the amount of velocity distortion (back to that old continuity equation) that actually occurs in a model. I don't think that issue has as much effect on the WES Movable-Bed Model, because stages were maintained in them. There may be an impact with the Micro-Model, but my guess is that the resulting stages in that type of model is lower than what would be representative of the prototype. However, I do not know this for a fact, so I took the values I calculated above as appropriate.

So where I ended was this:

MODEL TYPE	REYNOLDS NUMBER (based on Dogtooth Bend)	FROUDE NUMBER (based on Dogtooth Bend)	DISCHARGE SCALE DISTORTION (LOW to HIGH)
PROTOTYPE	$6.755X10^6$ - turbulent	0.1057 - subcritical	0.0 to 0.0
WES MOVABLE-BED	$2.1X10^3$ - turbulent	0.3524 - subcritical	2.9 to 0.0
MICRO-MODEL	$1.1X10^3$ - transitional	0.6221 - subcritical	4.6 to 4.2

In my opinion, the Micro-Model shows up here as being the most remote from typical open channel flow. Being in transitional flow and having a relatively high Froude number tells me that the flow is going to be approaching smooth, fast flow conditions, particularly at the water surface. When the fact is added that the model discharge is highly distorted relative to the Froude theoretical value, the exaggeration of the velocities is going to be enhanced.

When I look at flow visualizations for the low and high flows presented in the Morgan City Micro-Model report, the observation and conclusion that I made was that there was very little difference between the two flows (and thus the velocities). That is supported based on what Rob presented in his thesis. All along I have contended that a Micro-Model, in the hands of an experienced river engineer and modeler, is of use for comparing the impacts of various river training alternatives on sedimentation trends and tendencies, but because of the inherent distortion required to conduct such studies in very short time frames, the velocities required in a Micro-Model diverge too far from the prototype to use, even in a qualitative manner, for evaluating velocity-related issues like navigation. Using Rob's words here, "there is nothing to be ashamed of" here. In my opinion, it is a limitation of the Micro-Model at this point in time. As the technology progresses in the future with other types of model sediment material or developing other methods of operation, then velocities in the Micro-Model may become more representative of the prototype and be more meaningful for interpretation.

Thomas J. Pokrefke, Jr., PE
Hydraulic Engineer
Coastal and Hydraulics Laboratory